Psychological and Physiological Stressors and Factors (PPSF)

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NASA Ames Research Center
January 15, 1999

http://vision.arc.nasa.gov/~al/aos/level2.html

Outline & List of Figures

PPSF

List Of Acronyms

AATT - Advanced Air Transportation Technology Program

ATC - Air Traffic Control

CAA - Cargo Airlines Association

CMM - Cognitive Models and Metrics

OAT - Office of Aerospace Technology

FAA - Federal Aviation Administration

fMRI - Functional Magnetic Resonance Imaging

HUD - Head-up Display

HSA - Hazardous States of Awareness

ITU - International Telecommunications Union

JSC - Johnson Space Center

KSC - Kennedy Space Center

OAT - Office of Aerospace Technology

PMM - Perceptual Models and Metrics

PPSF - Psychological and Physiological Stressors and Factors

PF - Physiological Factors Subprogram

RTCA - Radio Technical Committee on Aeronautics

SA - Situation Awareness

SFO - San Francisco Int'l Airport

TAP - Terminal Area Productivity

TCAS - Traffic Collision Avoidance System

UL/SHFE - Space Human Factors Program

VE - Virtual Environment

Goals And Objectives

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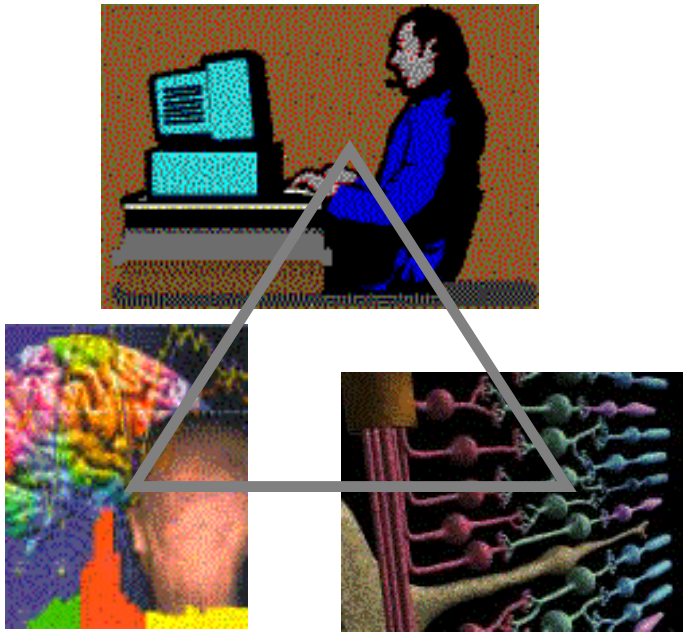
GOAL

- Supports NASA goal of enhanced safety.
- Seeks new knowledge about human information processing capabilities relating to displays, controls, interfaces and procedures, for safe and efficient management of the increasingly dense air traffic system



Objectives

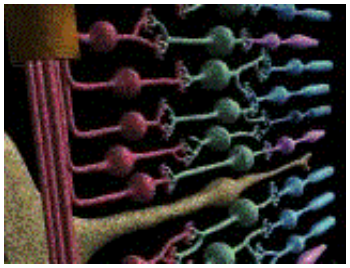
Develop and disseminate new knowledge in:

- Perceptual Models and Metrics
- Cognitive Models and Metrics
- Physiological Factors

Apply knowledge to:

- Optimize operator interaction with displays and controls
- Optimize operator information processing
- Reduce or prevent hazardous states of awareness

Project Approach



Perceptual Models and Metrics

Develop new methods, computational models, and metrics that will enable optimization of operator sensory-motor interaction with the displays and controls of the national air space system

Cognitive Models and Metrics

Develop new models of the human operator information processing during interaction with the air transportation system with the goal of understanding how operator attention may be directed or misdirected by the system

Physiological Factors

Provide knowledge about physiologically and behavioral correlates of alertness, fatigue, and other mental states with the goal of reducing human error and optimizing performance

Tasks

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Perceptual Models and Metrics (New Safety)

Visibility Models & Metrics →

Eye-Movement Metrics for Monitoring Human Perception

Image Processing and Image Understanding

Metrics & Models of Human Range/Closure Perception

Metrics & Models for the Perceptual Design of Virtual Transparency →

Spatial Auditory Displays →

L1 Milestone (FY01)

Complete guidelines for perceptually matched dynamic 3-D auditory displays and image fusion

Cognitive Models and Metrics (New Safety)

Eye-Movement Metrics for Human Cognitive Analysis & Modeling

Models & Metrics of Human Executive Control

Models & Metrics of Human Spatial Attention and Memory

Physiological Factors (Base)

Hazardous States of Awareness

Deliverables

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Perceptual Models and Metrics

- Computational models and metrics that predict perceptual system performance
- Display technologies that exploit understanding of perceptual systems

Cognitive Models and Metrics

- Models of the cognitive components of task execution
- Applications of models to analyses of human error
- New techniques for measuring complex performance

Physiological Factors

- Methods for identifying hazardous states of awareness, such as complacency, boredom, and preoccupation, in automated systems using physiological and behavioral measures
- Countermeasures for hazardous states of awareness
- Dual-use applications within aeronautics and in areas such as process control and medicine

Deliverables documented in scientific research papers and presentations

Project Funding

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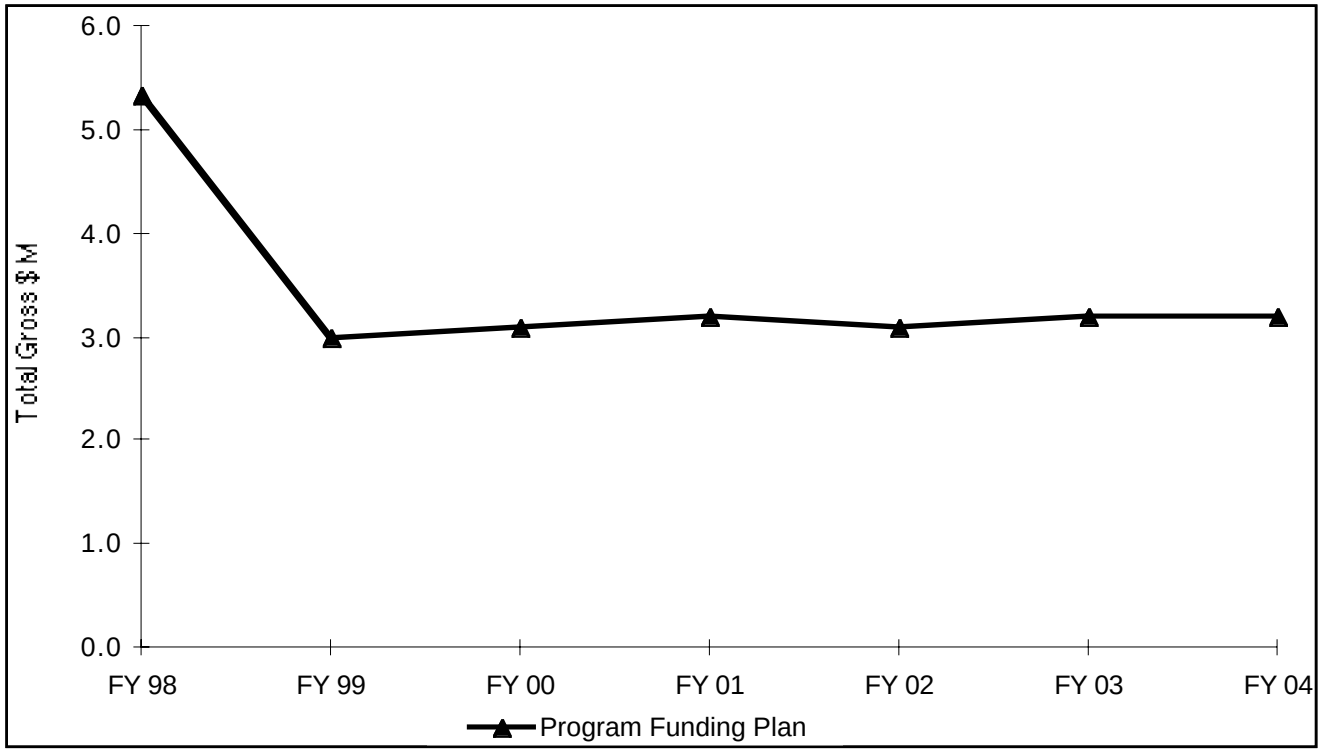

Program Funding Plan	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	Total
Net Totals	3.0	1.5	1.9	1.7	1.7	1.8	1.8	13.4
Program Support	2.3	1.5	1.2	1.5	1.4	1.4	1.4	10.7
Total (Gross)	5.3	3.0	3.1	3.2	3.1	3.2	3.2	24.1

Outside Relationships

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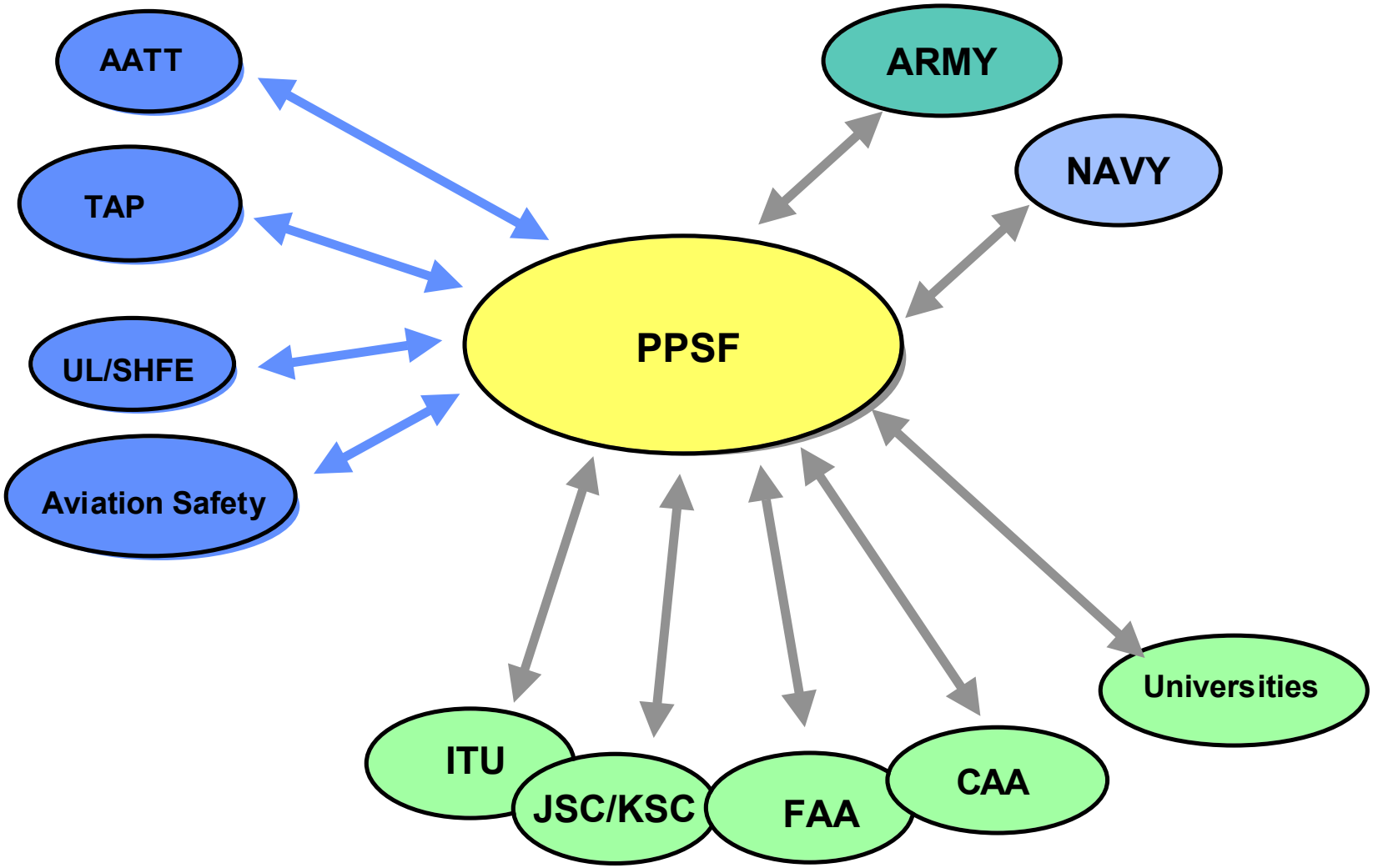

Technology Transfer

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Product	Standards & Requirements / Partners / Customers

Publications & Presentations (4/97-8/98)

Refereed Articles	29
Conference Papers	31
NASA Tech Reports	4
Invited Talks	9

IDEA — Interactive data-analysis software package for handling eye-movement data currently under joint development by NASA and the Salk Institute

DCTune — Software demo of perceptually-lossless image compression (two patents, both on web, http://vision.arc.nasa.gov/dctune/dctune2.0.html)

Ames Spatial Auditory Display

Three prototypes based on the Begault (1995) patent were developed for KSC and JSC for multiple-channel speech communications

MOU with NAVY (SPAWAR)

Transferred technology for the development of three-dimensional sound and visual displays for SONAR and battle-station applications

Major Accomplishments (4/97-8/98)

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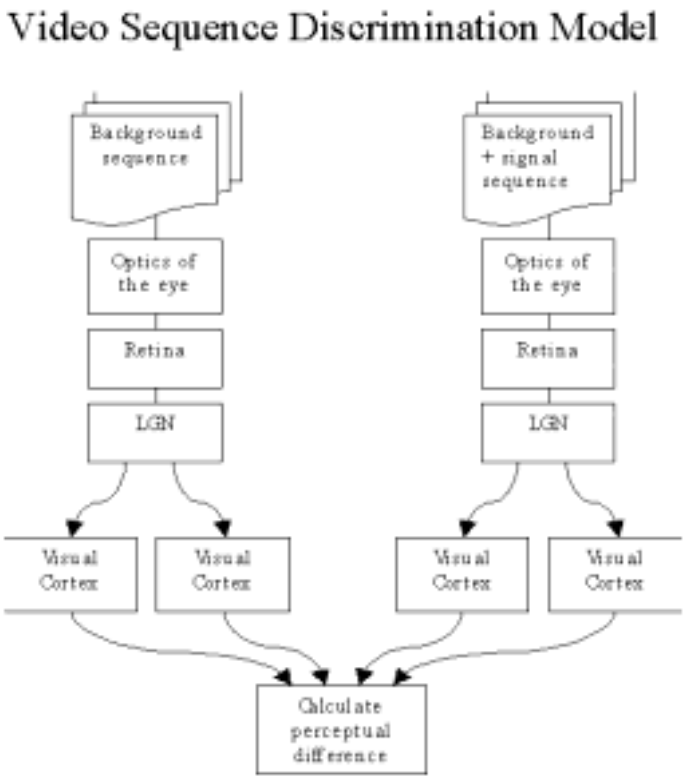
Perceptual Models and Metrics
Task: Visibility Models and Metrics

Objective: To develop algorithms that predict whether an observer can detect targets in images (visibility models) or see differences between images (image quality metrics).

Accomplishment: Developed video discrimination models and presented them to the vision and display communities.

- A. Ahumada, B. Beard, R. Eriksson, "Spatio-temporal discrimination model predicts temporal masking functions," Human Vision and Electronic Imaging III, SPIE Proc. Vol. 3299, 1998.
- A. Watson, "Estimating video quality with a vision model." Invited presentation to the European Conference on Visual Perception, Oxford, England, Sept. 1998.



Major Accomplishments (4/97-8/98) cont'd

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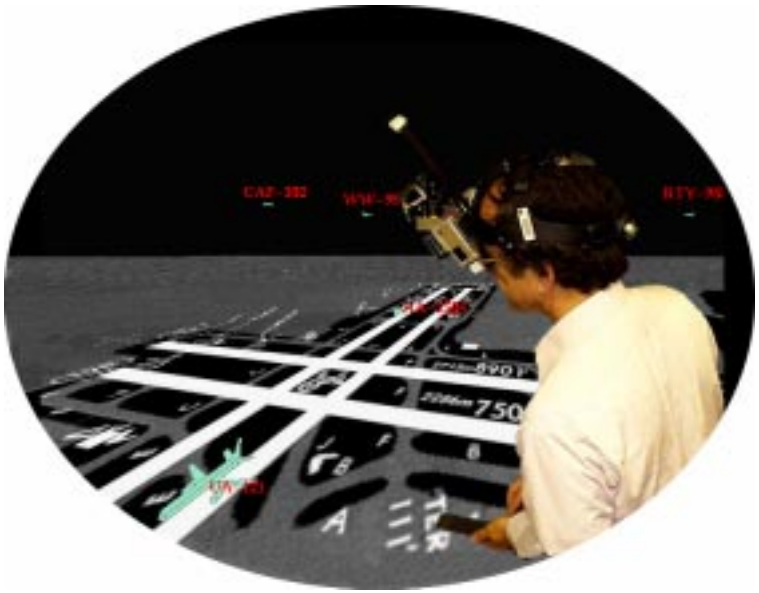
Perceptual Models and Metrics. Task: Metrics and Models for the Perceptual Design of Virtual Transparency



Problem: Low visual and low dynamic fidelity in VE simulation due to high cost of high fidelity hardware and software.

Objectives:
- Improve dynamic fidelity of virtual ATC displays
- Accurately render depth of virtual aircraft

Accomplishments:
- Upgraded head position measurement system allowing rendering with full system latency of 25 ms and 60 Hz stereo update rate
- Completed four experiments studying the impact of latency on manipulative precision and the sense of depth derived from motion parallax
- Determined that VE systems will need very low latency for practical use, e.g. 1 ms of latency may be tolerated for each mm of required precision.
- A virtual ATC Tower simulation has been completed (for SFO or Atlanta airports)

Major Accomplishments (4/97-8/98) cont'd

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Perceptual Models and Metrics. Task: Spatial Auditory Displays

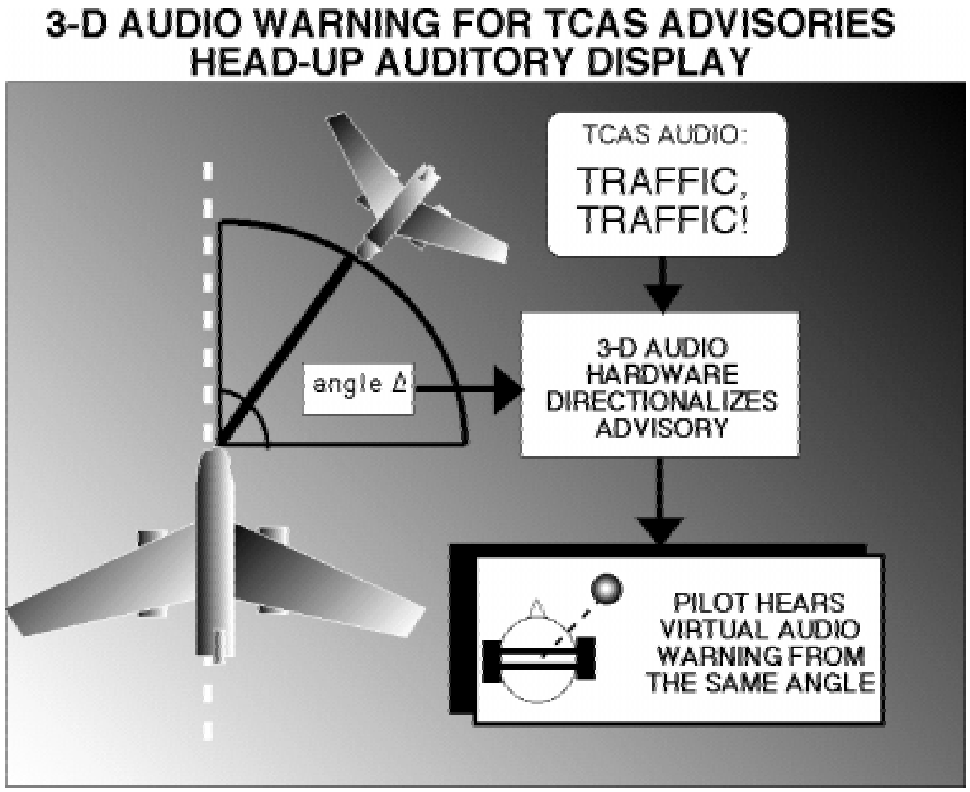
Goal: Develop 3-D auditory HUD for aurally-guided visual search

Benefits:

- Faster target acquisitions
- Better visual concentration
- Promotes situation awareness
- Uses existing 3-D audio technology

Status:

- Completed three full-mission sims
- Found 2.2 sec advantage with 3-D audio HUD
- Submitted manuscript to journal Human Factors



Major Accomplishments (4/97-8/98) cont'd

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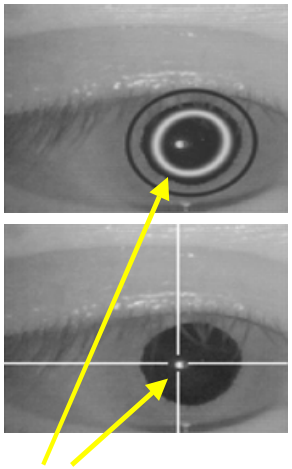
Perceptual Models and Metrics. Task: Eye-Movement Metrics for Monitoring Human Perception

Video Monitoring of Operator Behavior



Head-mounted camera system for remote use
- infrared eye camera
- forward-looking scene camera

Determination of gaze by analysis of eye images

Composite scene mosaic derived from many images

Input image registered to scene to derive head position

Objectives: 1) Eye-movement metrics for design and evaluation of training, displays, and interfaces.
2) Visual-motor control models that predict display conditions that promote human errors.

Accomplishments:
1) New head-mounted technology for auto-mated gaze analysis
2) Guided Search Model
3) 5 articles and 9 conference papers

Major Accomplishments (4/97-8/98) cont'd

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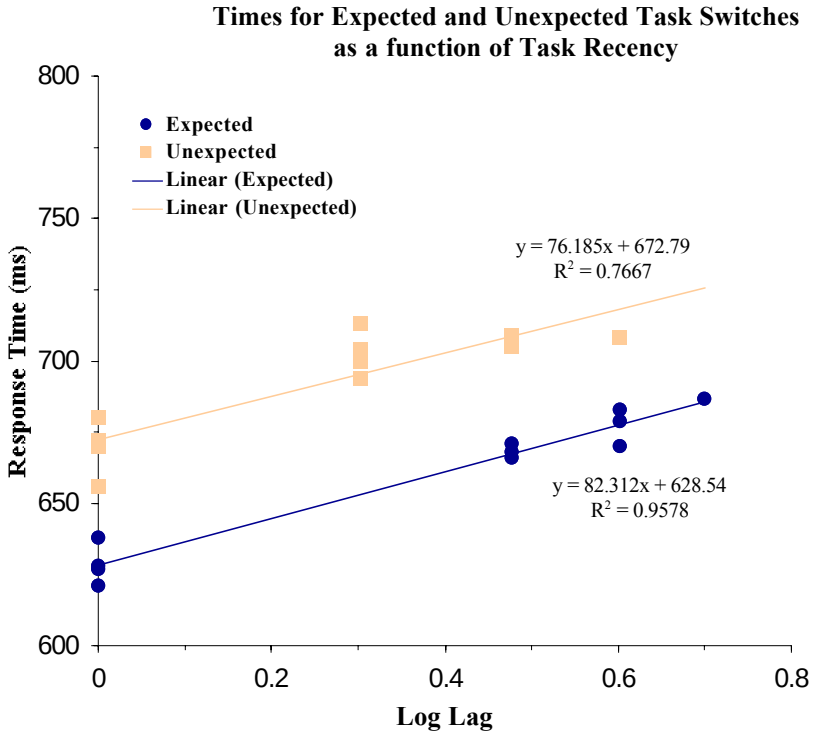
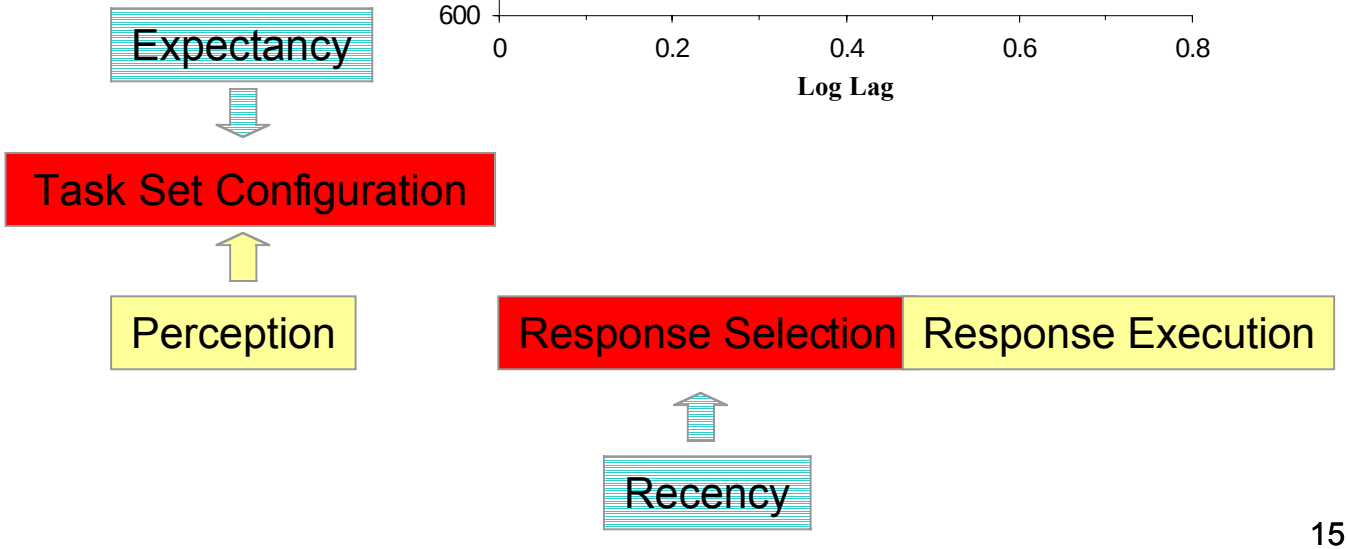
Cognitive Models and Metrics. Task: Models and Metrics of Human Executive Control

- **Additive Effects of Expectancy and Recency explained by the dual-locus model**
  - Expectancy affects the time to configure a Task Set (can begin before task onset)
  - Recency affects efficiency of response retrieval
- **Task Set Configuration and Response Selection cannot proceed concurrently**



Dual-Locus Model



Major Accomplishments (4/97-8/98) cont'd

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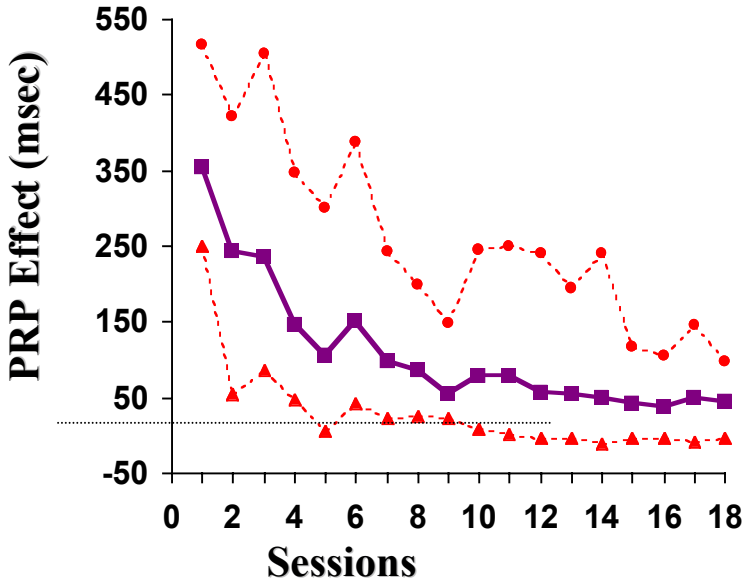
Models and Metrics of Human Executive Control (cont'd)

Effects of Practice on Dual-Task Interference

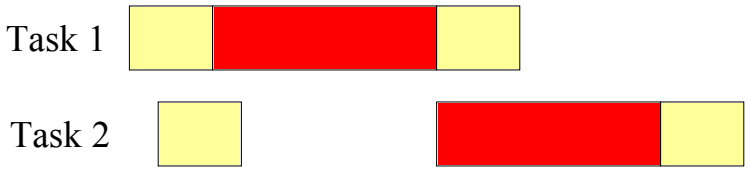
- Dual-task interference is important limitation on operator throughput
- Question: Can practice reduce or eliminate dual-task interference?
- Approach: Use Psychological Refractory Period paradigm with extensive training



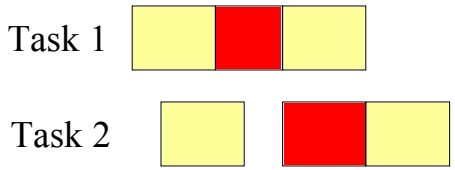
Conclusions

- Practice reduces dual-task interference
- Reduction possible only if tasks have different response modalities (e.g. vocal-manual)
- Primary cause of reduction is shortening of central processing stages
- Secondary cause is increased ability to overlap central processing stages
- Pattern of effects shows residual interference is explained by central bottleneck model

Bottleneck with low practice



Bottleneck with high practice



Other Accomplishments (4/97-8/98)

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Perceptual Models and Metrics. Task: Metrics and Models of Range and Closure Perception

Objective:

- Provide guidelines for perspective displays for vehicular control, and evaluation tools to determine the likelihood of pilot error/disorientation under various display and visibility conditions.

Approach:

- Develop models for human performance and evaluate their ability to predict human performance (especially errors) in low,mid, and high-fidelity vehicle control simulations.

Accomplishment:

- Completed preliminary testing and design of two experiments for active-control, depth-cue integration studies.

Other Accomplishments (4/97-8/98) cont'd

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Cognitive Models and Metrics. Task: Eye-Movement Metrics of Human Cognition

Objective:

- Develop direct tests of the usefulness of eye movements for inferring behaviors of interest.

Approach:

- Explore tasks for which the information requirements are well understood, e.g., judgments that entail the use of altitude information
- Test whether eye movements directly reflect information

Accomplishments:

  - 1st Quarter: Identified requirements for eye fixation monitoring equipment
  - 2nd Quarter: Established collaborative agreement with Stanford University to explore fMRI methods for analyzing complex performance
  - 3rd Quarter: 1) Purchased eye movement monitoring equipment. 2) Completed the design and programming of fMRI experiments testing brain mechanisms active in concurrent task management
  - 4th Quarter: Began testing subjects in fMRI experiment on concurrent task management

Other Accomplishments (4/97-8/98) cont'd

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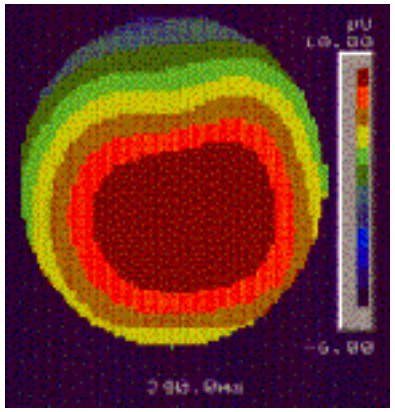
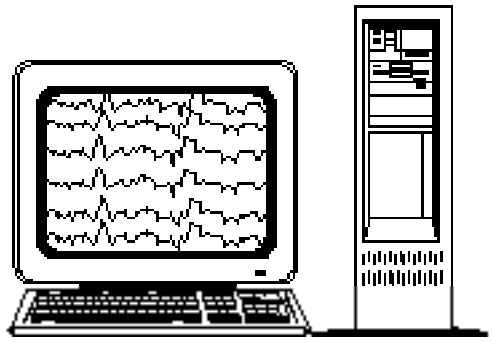
Physiological Factors. Task: Hazardous States of Awareness





Objectives: 1) Develop and validate techniques for identifying hazardous states of awareness in automated systems.
2) Demonstrate dual-use applications of methods

Hazardous States:
- Complacency
- Boredom
- Blocks
- Task-Unrelated Thoughts
- Lapses and Slips
- Mental Fatigue

Measurement Technologies:
- Task performance control inputs, errors
- Subjective reports
- Physiological techniques
- State-of-the-art analyses

Accomplishments:
- Established Taxonomy of Hazardous States of Awareness (HSA)
- Reviewed HSA Candidate Measurement Techniques
- Report: M. W. Scerbo *et al. Hazardous States of Awareness: Functional Characteristics and Measurement*. Old Dominion University Final Report, Task Assignment 113, NASA Contract NAS1-19858.

Project Assessment

	3Q98	4Q98	1Q99	Remarks
Project Overall Assessment	G	G	G	
Technical Performance	G	G	G	
Cost	G	G	G	
Schedule	G	G	G	

Guidance:

Assessment & L2 Judgement Performance

Cost	*-5% Yellow*
	-15% Red
Schedule	*-1Q Yellow*
	-2Q Red

Summary

Science and Technology

- Perceptual Models & Metrics
  - Visibility Models & Metrics
  - Eye-movement Models & Metrics
  - Image Processing / Understanding
  - Virtual Environments
- Cognitive Models & Metrics
  - Executive Control
  - Attention
  - Oculometric Analysis of Cognition
  - fMRI Analysis of Cognition
- Physiological Factors
  - Electrophysiolgical Brain Mapping
  - Behavioral/physiological Analysis
  - Biomedical Signal Processing

Products

- Improved Navigational Displays
- Improved ATC Displays
- Improved User Interfaces
- 3-D Audio Enhanced Displays
- Virtual / Transparent ATC Displays
- Improved Situational Awareness
- Improved Cognitive Task Engineering
- Safer Procedures
- Management of Hazardous Mental States

Reduced Operator Error / Lower Aviation Accident Rate